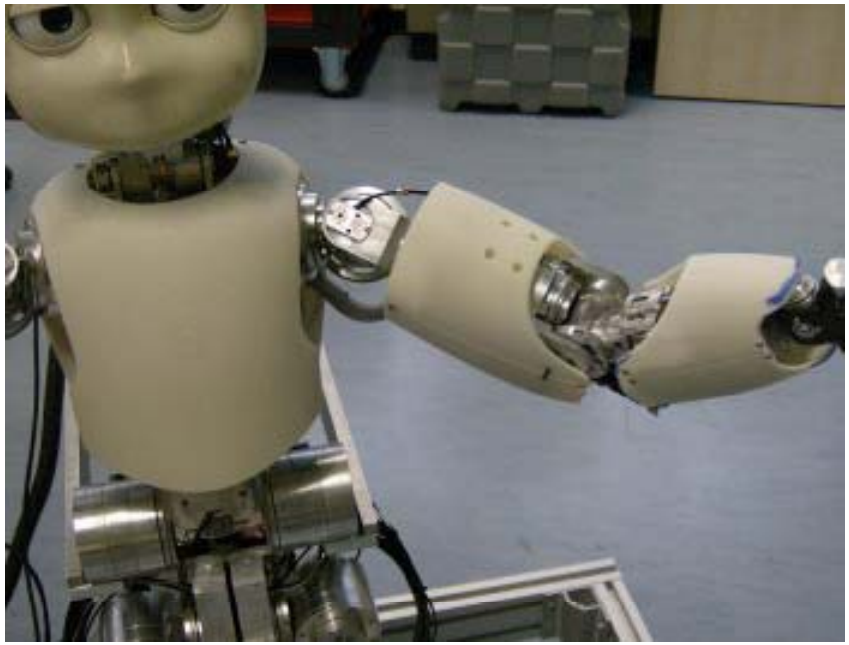


The RobotCub project

November 26th

ICT2008, Lyon

Cogsys
Cognitive Systems

RobotCub.org

Collaborations the RobotCub Consortium

U. of Genoa/IIT	Scuola S. Anna	U. of Zurich	U. of Uppsala	U. of Ferrara
Giulio Sandini	Paolo Dario	Rolf Pfeifer	Claes von Hofsten	Luciano Fadiga
Giorgio Metta	Cecilia Laschi	Harold Fernandez	Kerstin Rosander	Laila Craighero
David Vernon	Giovanni Stellin	Gabriel Gomez		Andrey Oleyinik
Lorenzo Natale				
Francesco Nori				
Paul Fitzpatrick				

U. Herthfordshire	IST - Lisbon	U. Sheffield/IIT	EPFL	Telerobot S.r.l
K. Dautenhahn	Jose' Santos-Victor	Darwin Caldwell	Aude Billard	Francesco Becchi
C. L. Nehaniv	Alexandre Bernardino	John Gray	Auke Ijspeert	David Corsini
René te Boekhorst	Ricardo Beira	Nick Tsagarakis	Sarah Degallier	
N. Assif Mirza	Miguel Praça		Ludovic Righetti	

Goals

- Advance our understanding of artificial cognition
  - By looking at natural cognition "first hand"
  - By building an experimental platform shaped as a humanoid robot child
  - By implementing plausible models of cognition on this robot platform
- RobotCub is a 5 years long FP6 Integrated Project
  - It finishes next year, but the outcomes would hopefully last longer ☺

RobotCub.org

ROBotic Open-architecture Technology for Cognition, Understanding and Behavior

Cogsys Cognitive Systems

Project No. 004370

RobotCub

Development of a Cognitive Humanoid Cub

Instrument: Integrated Project
Thematic Priority: IST - Cognitive Systems

D2.1 A Roadmap for the Development of Cognitive Capabilities in Humanoid Robots

Due date: **01/09/2007**
Submission Date: **07/10/2007**

Start date of project: **01/09/2004** Duration: **60 months**

Organisation name of lead contractor for this deliverable: **University of Genoa**

Responsible Person: **David Vernon**

Latest version is 6.2

Cogsys Cognitive Systems

Cognition

Cognition: a process by which a system achieves behaviour that is

- robust
- adaptive
- anticipatory
- autonomous

Entails embodied perception, action, and interaction

iCub Cognitive Architecture

Grounded in neuroscience and psychology

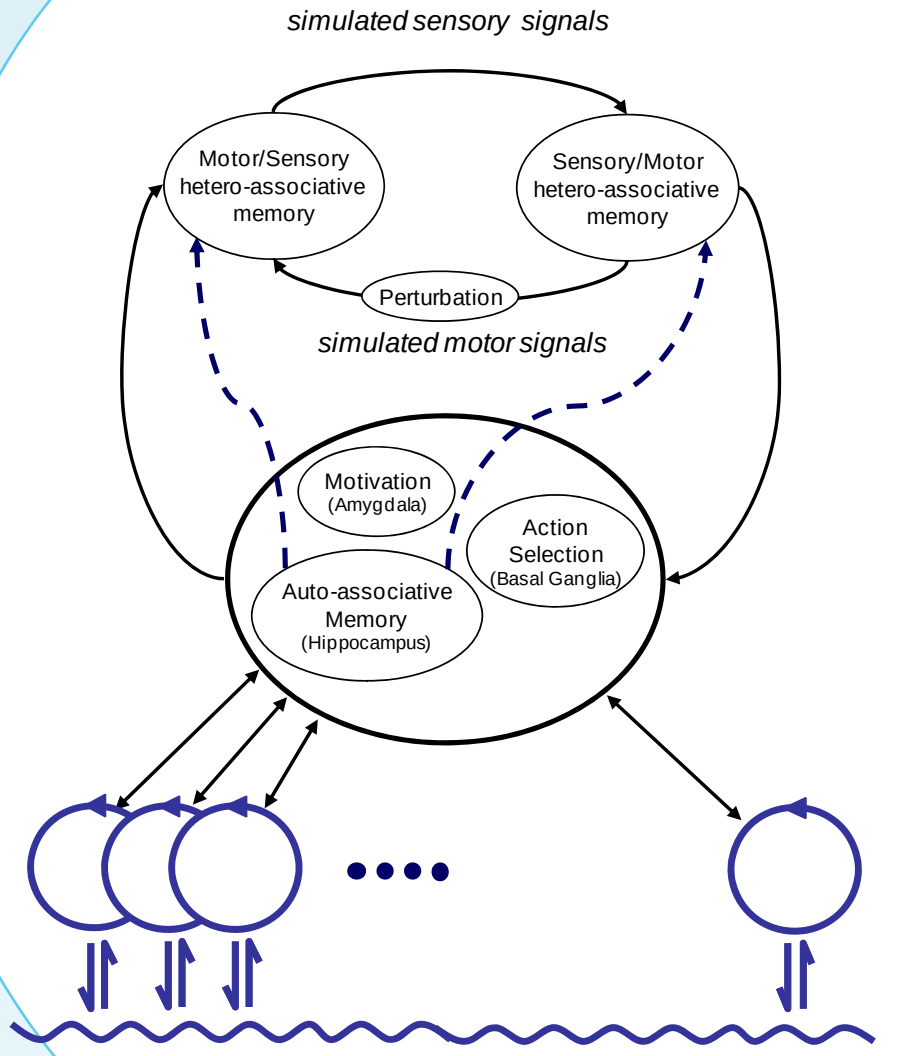
Rooted in action-dependent perception

Focussed on adaptive & prospective capabilities

Designed to facilitate development

Cognitive architecture ≡ (iCub) Phylogeny

We started from a "paper" design



Prospection by action simulation

Modulation circuit: homeostatic action selection by disinhibition of perceptuo-motor skills

Phylogenetic self-organizing perceptuo-motor skills

Empirical Investigation 1

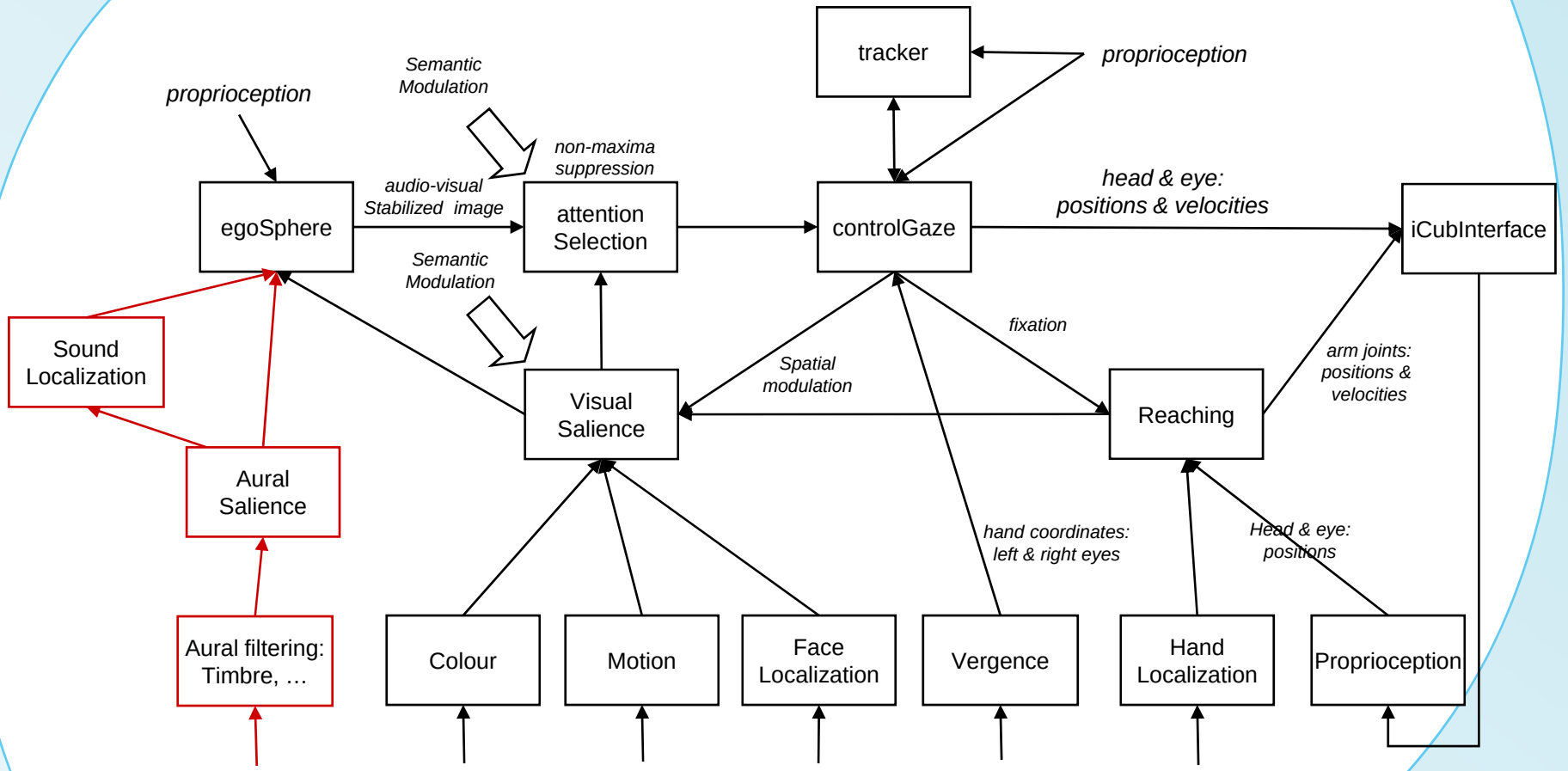
- Source: RobotCub deliverable 2.1 (Image:Investigation1.pdf)

Situation: The icub "sits" in a special chair that gives support to the head and legs while the arms are fre

Contents [hide]

Looking

- 1. A face pattern is introduced into the peripheral visual field (30° from the centre) . The visual angle c to position the face at the centre of the visual field. They both starts at the same time, but the eyes a gaze stay at the fixation object while the eyes counter rotate until they look straight ahead again. Th visual field or when a sounding object is introduced to the side of the robot (30-50°). New objects that
- 2. The robot turns its head (10-20°) while fixating an object or a face (10-30°). The eyes of the robot w
- 3. An object moves into the visual field. Its average velocity is 8-25°/s. The robot makes a saccade to object makes repetitive turns the robot should turn its eyes with the motion with no lag. When the tur adjustments may have smaller amplitude than the object motion and the difference will then be comp the gaze adjustments will better adjusted to the object motion.
- 4. An object moves in the visual field and gets temporarily occluded behind some other objects. The the occluder. The saccade will predict when and where the object will appear.



A, V, P - aural, visual, and proprioceptive sensory information

iCub YARP module specifications

iCub software is organized and implemented as a collection of YARP executable modules. When approp
appropriately connected YARP ports) these modules implement the required iCub capabilities.

The following iCub YARP modules are available.

```
armMover
attentionSelection
camCalib
camCalibConf
controlGaze
crossPowerSpectrumVergence
dsReaching
stereoVisualTracker
egoSphere
fggui
gaitControl
handLocalization
headTracker
histogramTracker
iCubInterface
learner
qSalienceGui
qControlBoardGui
reaching
reachingLearner
salience
simpleClient
tracker
yarpdev
```

There is a list of the dependencies between these modules and other resources here: module dependenc

lasaBodySchema

[iCub applications]

This application performs reaching and gazing while learning the head and arm body schema, (i.e. More...
something equivalent to the D.H parameters of the robot)

Dependencies

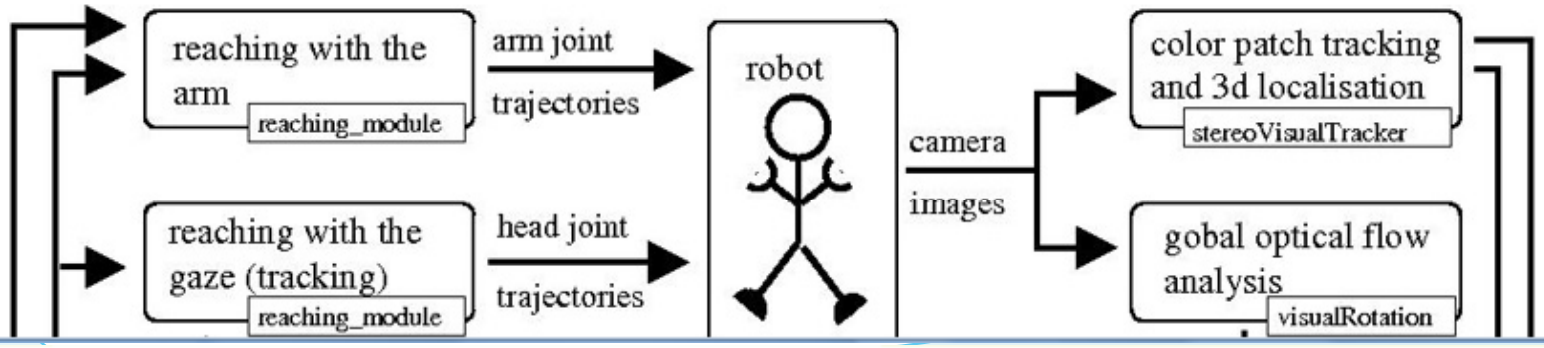
- It assumes that **velocityControl** for the part you are using is running
- It also assumes that **iCubInterface2** is running
- It also assumed that **stereoVisualTracker** is running
- For full functionality **visualRotation** is also assumed to run.

Instantiated Modules

The following modules are instantiated:

- A **reaching_module** for reaching with the arm
- A second instance of **reaching_module** for reaching with the head (in other words gazing)
- A **body_schema_learning** for learning the body schema
- A **head_transfo** for converting visual data from head-centered to body centered coordinates
- A **kinematic_simulator** for visualizing what is going on,

Here is how they are interconnected



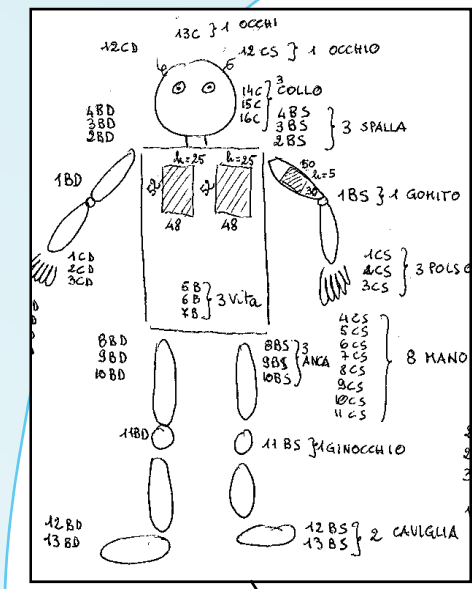
still

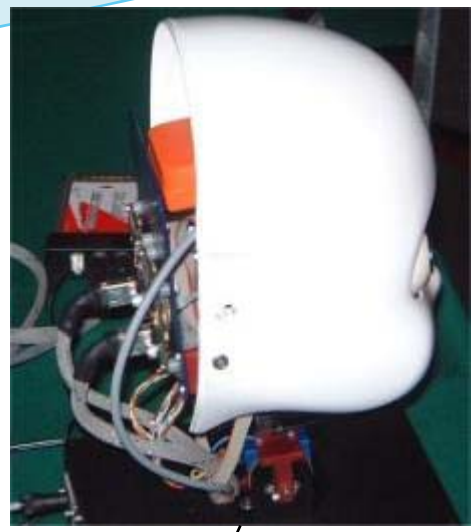
Two challenges ~~now~~ face the project

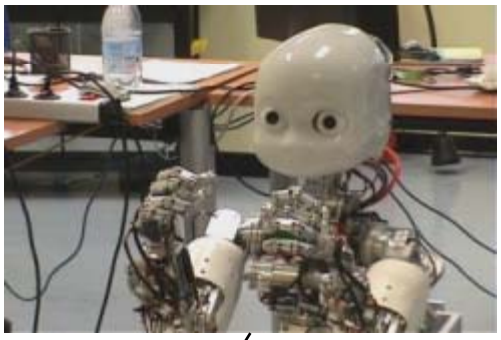
1. Consolidate the software architecture and complete its implementation

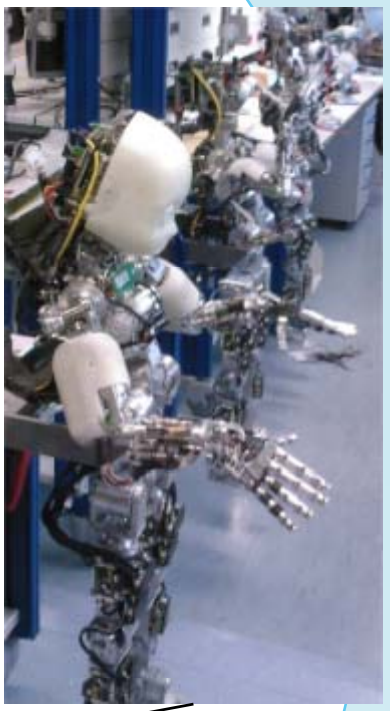
2. Add on more ontogenetically-motivated functionality to facilitate learning and development, *i.e.* more cognitive behaviour.

RobotCub









Month 0 | Month 12 | Month 24 | Month 36 | **Month 48** | Month 60

Cogsys
Cognitive Systems

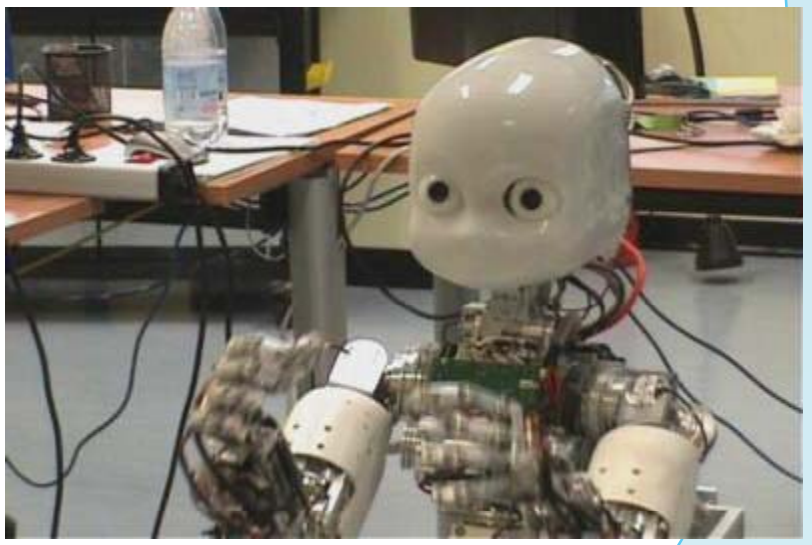
The iCub: quick summary

The **iCub** is the humanoid baby-robot designed as part of the **RobotCub** project

- The iCub is a full humanoid robot sized as a three and half year-old child.
- The total height is 104cm.
- It has 53 degrees of freedom, including articulated hands to be used for manipulation and gesturing.
- The robot will be able to crawl and sit and autonomously transition from crawling to sitting and vice-versa.
- The robot is GPL/FDL: software, hardware, drawings, documentation, etc.

Degrees of freedom

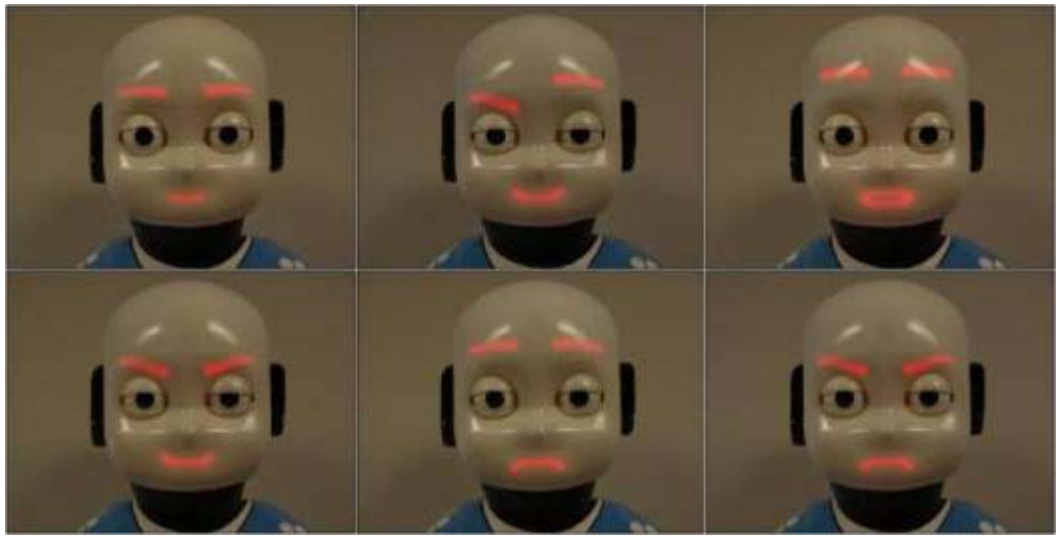
- Head: vergence, common tilt + 3 dof neck
- Arms: 7 dof each
  - Shoulder (3), elbow (1), wrist (3)
- Hands: 9 dof each ► 19 joints
  - 5 fingers ► underactuated
- Legs: 6 dof each
  - Hip (3), knee (1), ankle (2)
- Waist: 3 dof

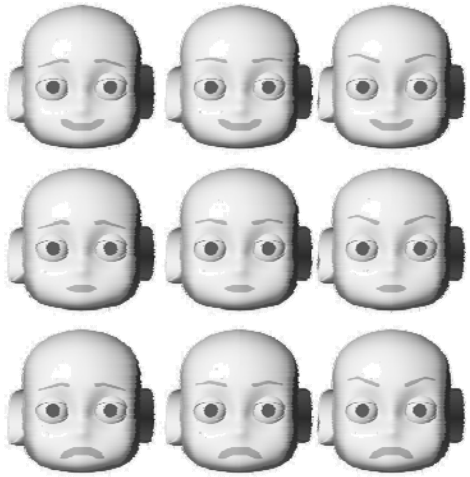


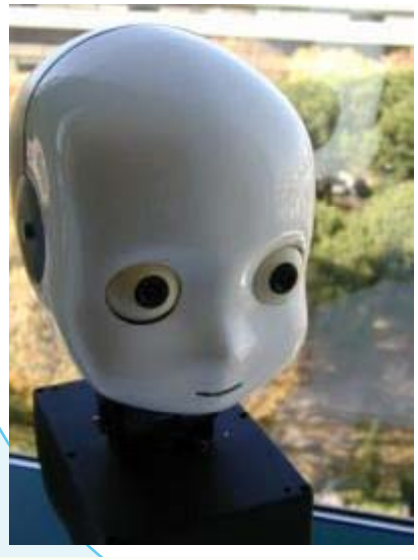
Σ = 53 dof (not counting the facial expressions)

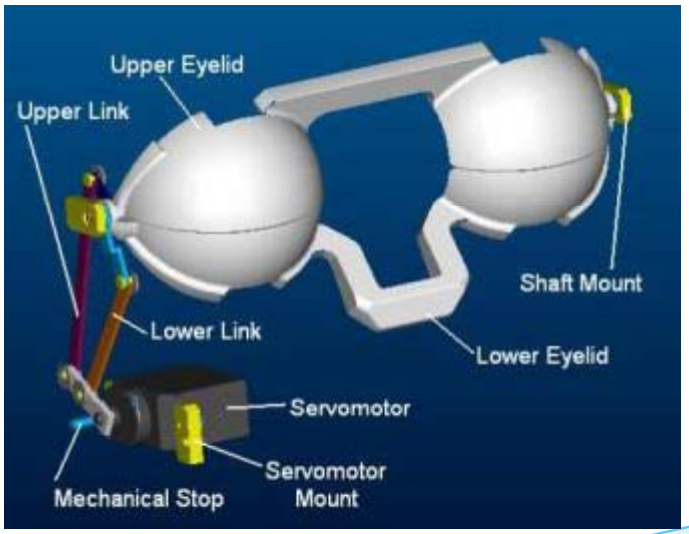
RobotCub

Facial expressions









Cogsys
Cognitive Systems

Sensorization

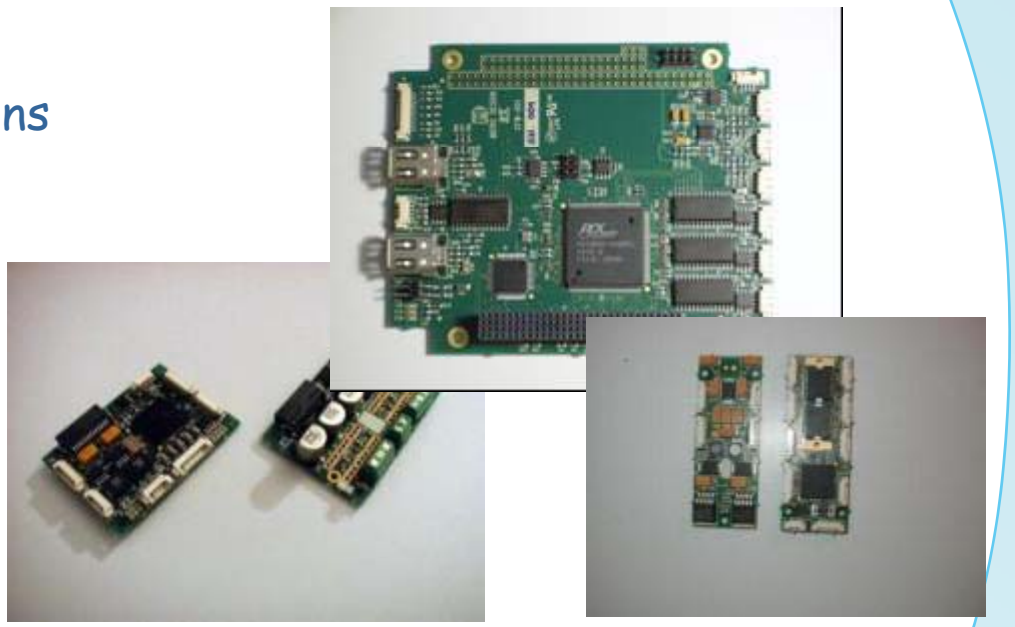
- For each joint:
  - Position (some absolute, some incremental):
    - Magnetic absolute position sensors
    - Encoders
    - Hall-effect sensors
  - Torque/tension
    - Limb level, but work in progress to add joint level torque sensing
    - Current consumption
  - Temperature (monitor, safety)
    - Safe operation (but we have a disclaimer now!)

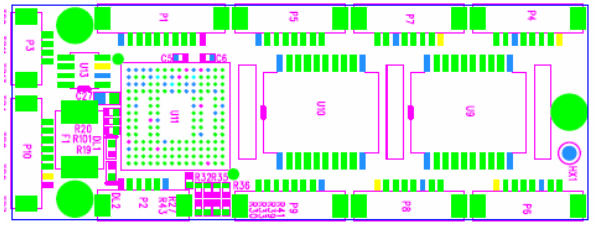
In addition…

- Cameras
  - Pointgrey Dragonfly firewire cameras
- Force/torque sensors
  - Custom development: 6 axial
- Microphones, speaker
  - Standard condenser electrect miniature microphones
  - Pinnae
- Gyroscopes, linear accelerometers
  - Xsense: Mtx
- Tactile sensors, skin, fingertips
  - Capacitive sensors (more later)

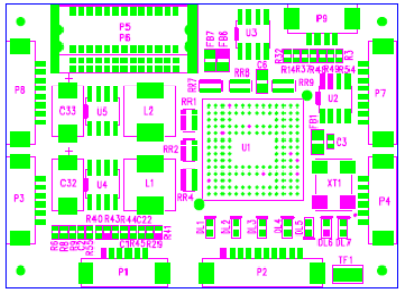
Custom electronics

- ADC card
  - Special connectors (40 pins < 1cm length)
  - 200µm stainless steel wires, coated in Teflon
- Motor control
  - C programmable DSP 40 MIPS
  - Up to 4A DC motor





80x30mm

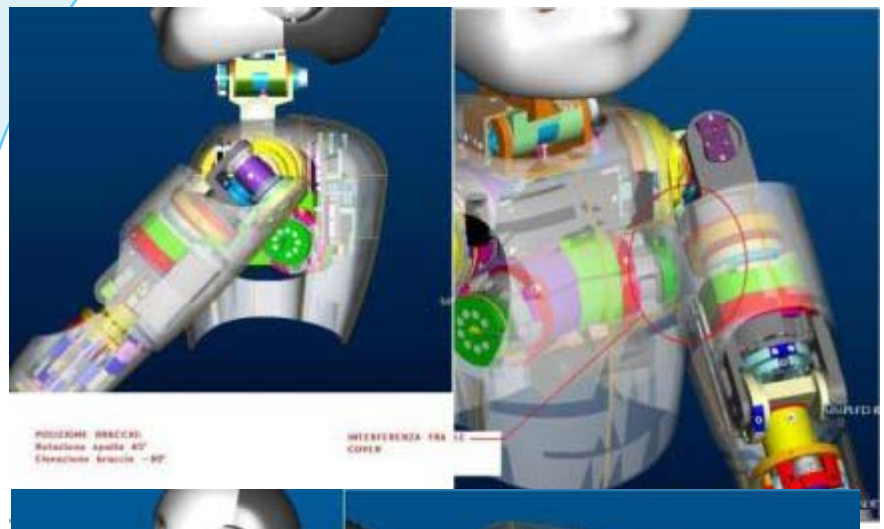


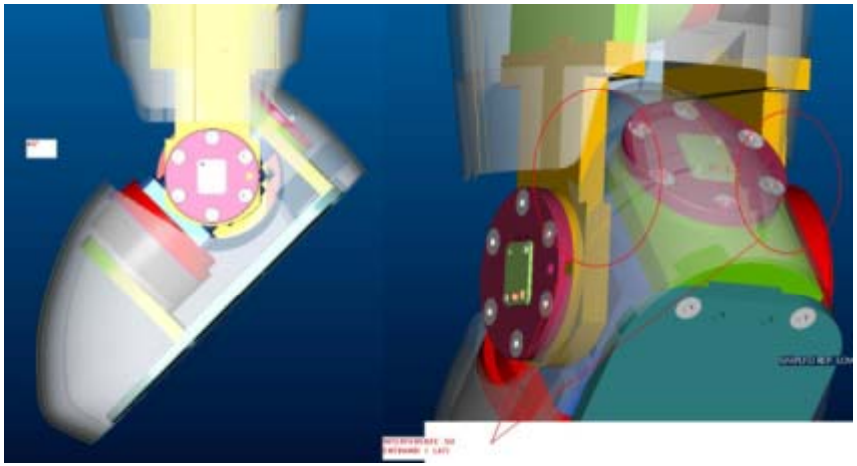
58x42mm

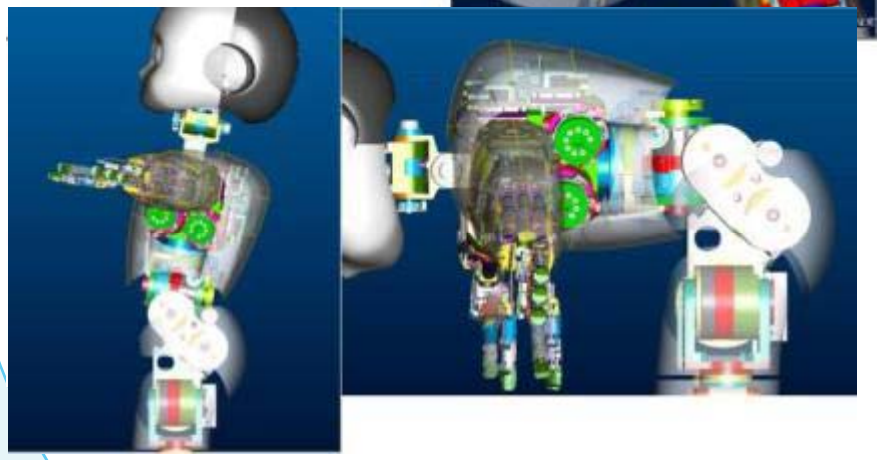
Motorola DSP56F807 (5680x family)
MAC instructions
PWM generation
ADC
Digital I/O
Can bus
C programmable

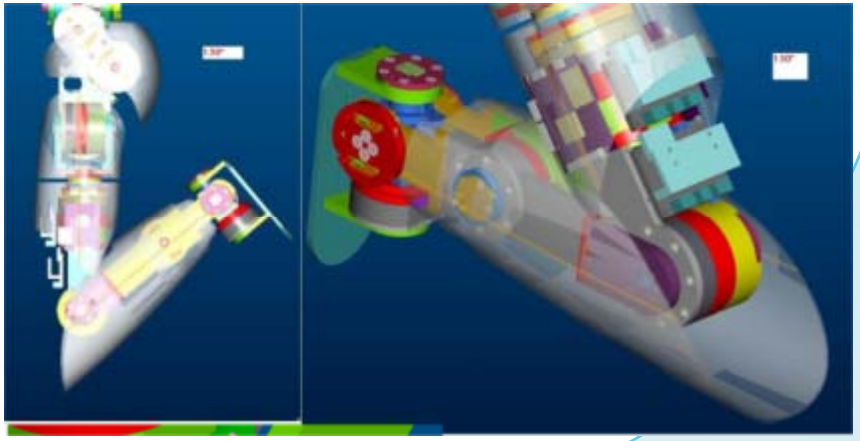
RobotCub

The iCub cover design









Cogsys
Cognitive Systems

RobotCub

YARP inside

Level 2 APIs: Prospective Action Behaviors

Coordinated operation: Ontogenic Development

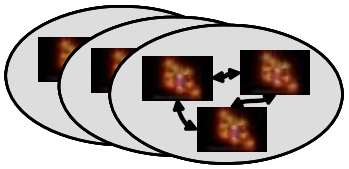
Level 1 APIs: perception/action behaviors

Based on phylogenic configuration

Innate perception/action primitives
loose federation of behaviors

own learning model

Level 0 APIs: data acquisition & motor control



Multiple YARP processes
Running on multiple processors

Gbit Ethernet

pc104: Yarp also here → HUB

DSP DSP ..... DSP DSP

Sensors & Actuators

Cognitive Architecture

Software Architecture

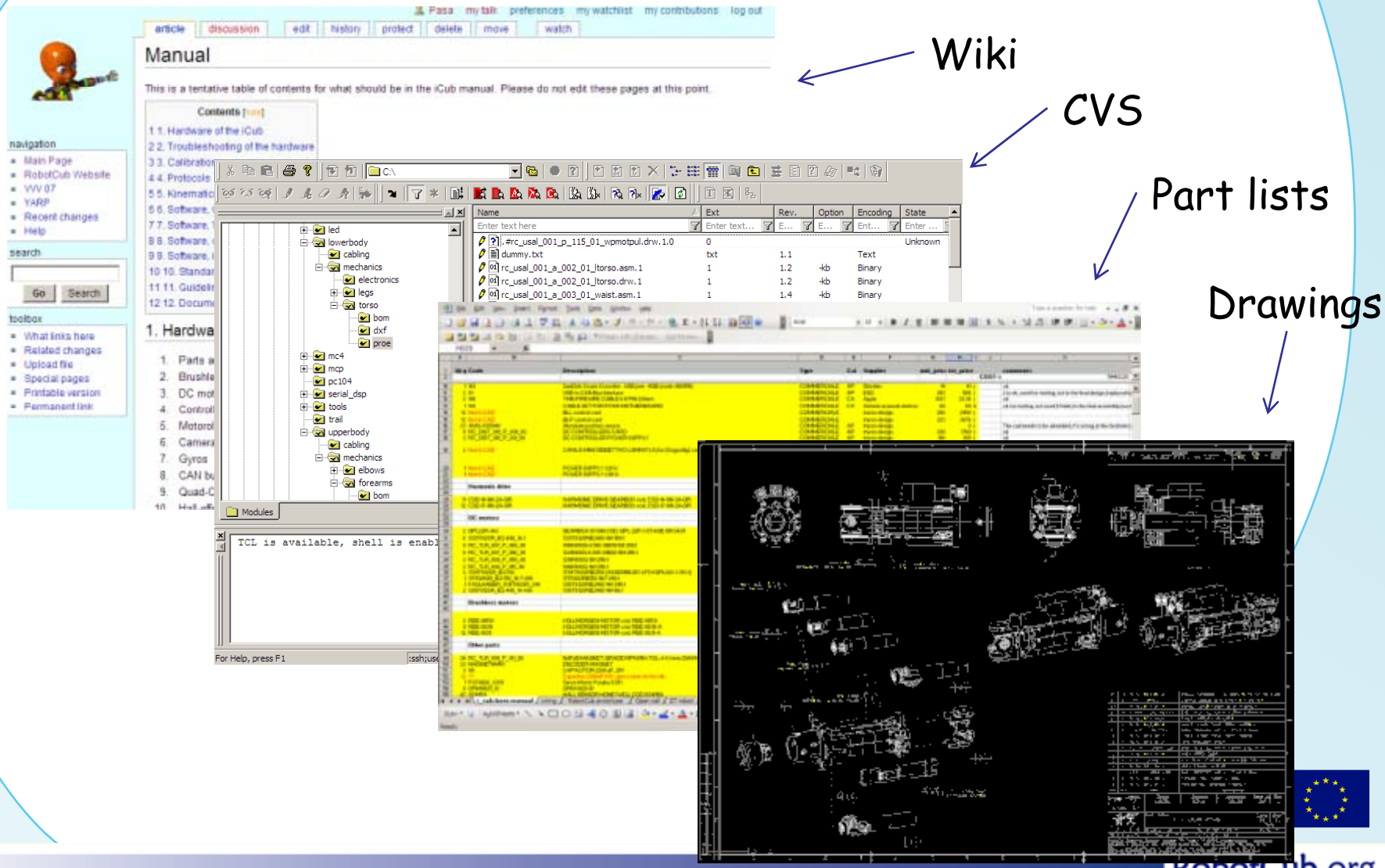
YARP: Middleware

iCub Embedded Systems

Cogsys
Cognitive Systems

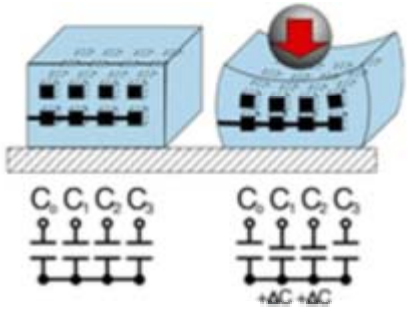
RobotCub

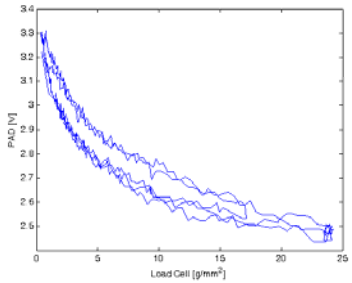
open source

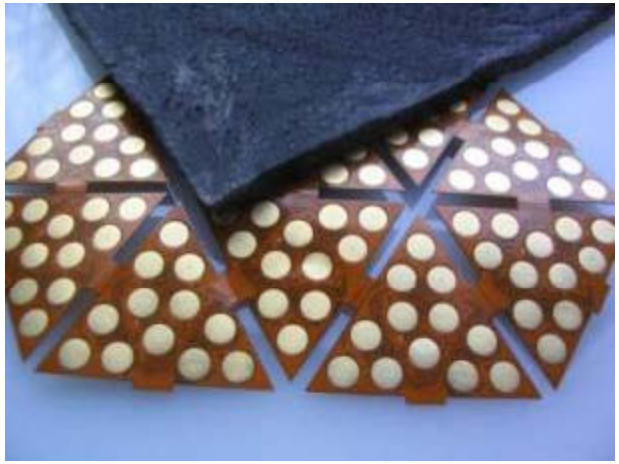


The skin (ideas…)

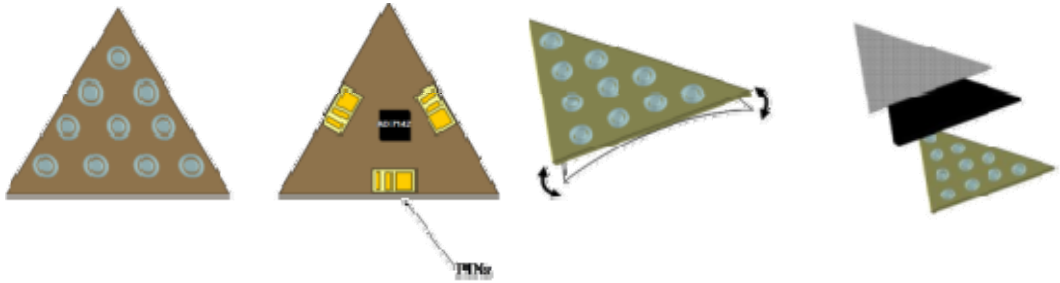
Principle



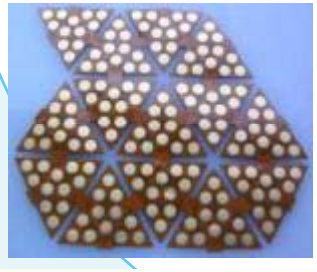


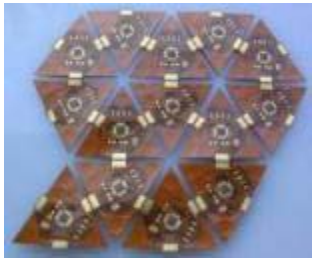


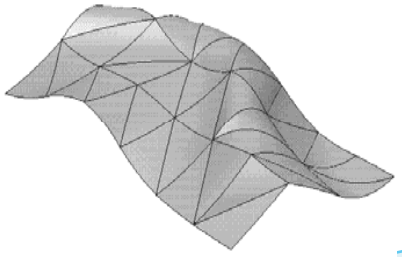
Lot of sensing points



Structure of the skin

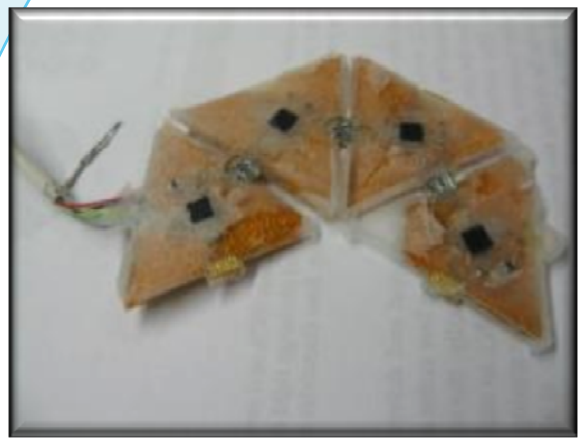






RobotCub

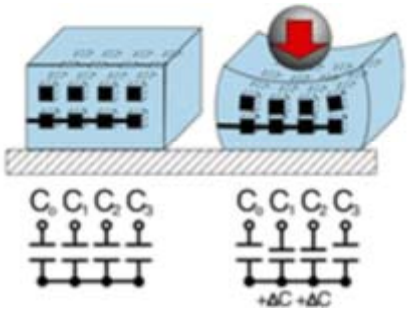
Some initial results



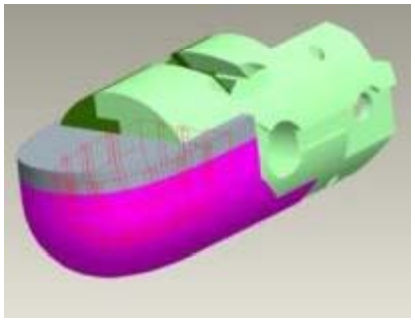



Cogsys
Cognitive Systems

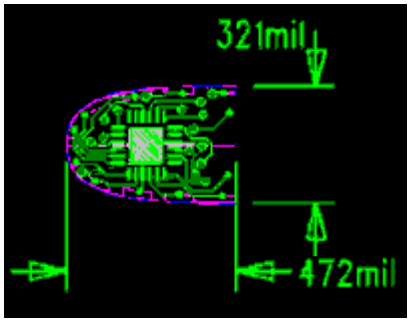
Fingertip



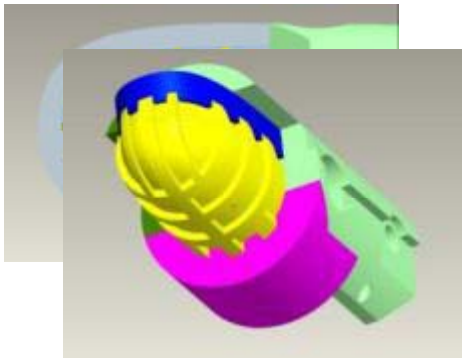
Outline



Silicon cover



Electronics

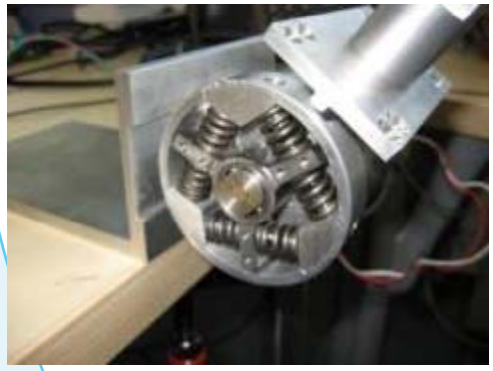


3D CAD

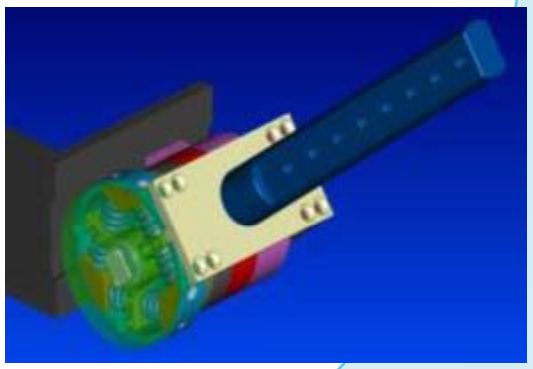
Electrode fabrication

Complete prototype

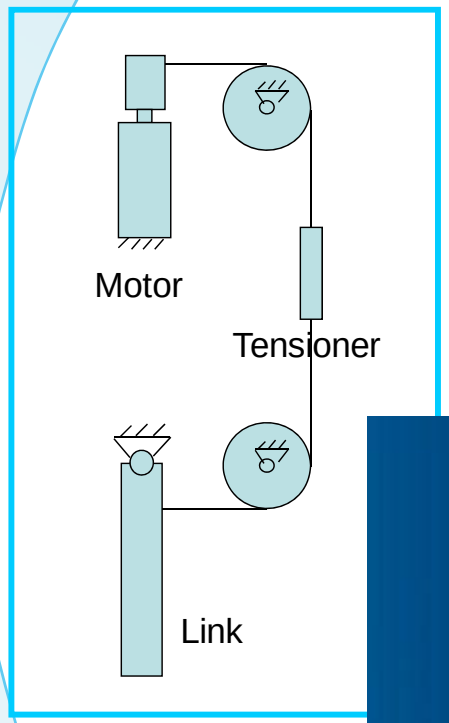
Compliant joints (SEL)

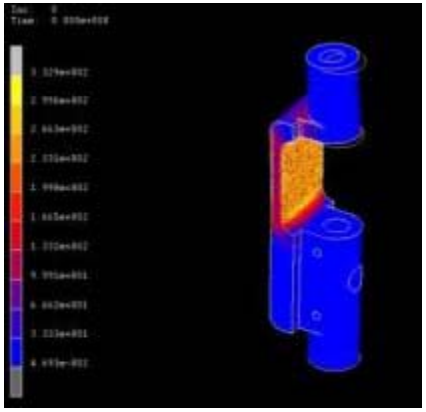


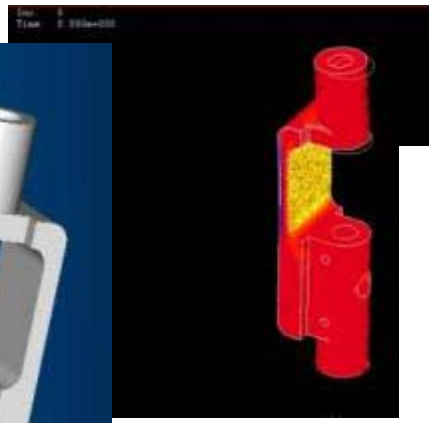
Diameter	70mm
Length	80mm
Power	190W
Gear Ratio	100:1
Peak Torque	40Nm
Max Rotary Passive Deflection	+/-0.18rad
Weight	0.52Kg

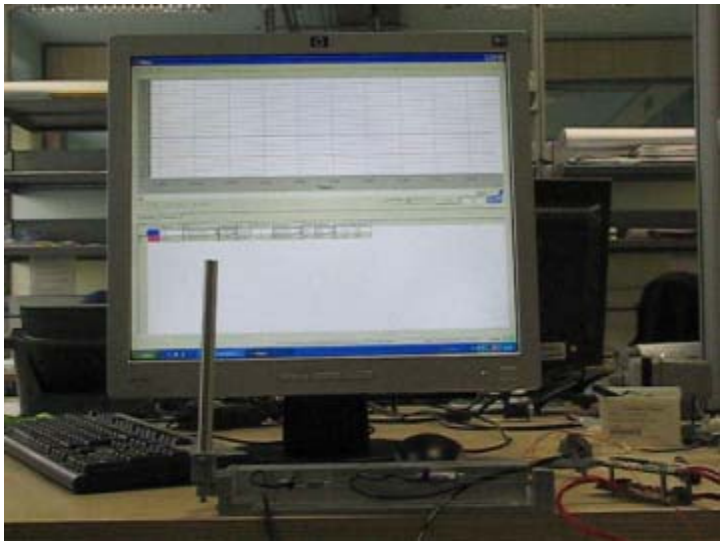


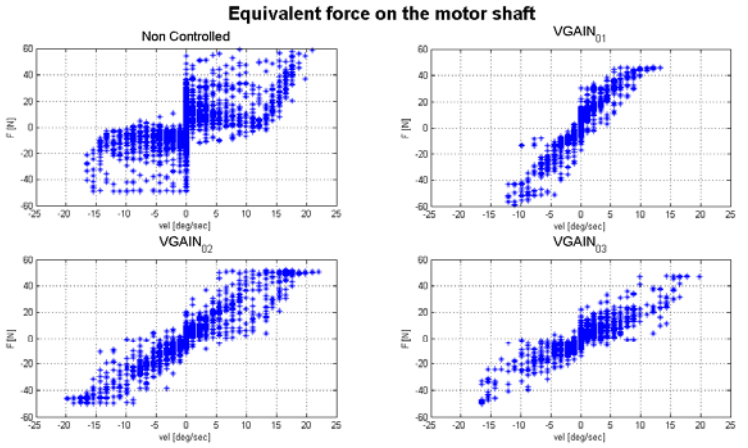
…or tension sensors





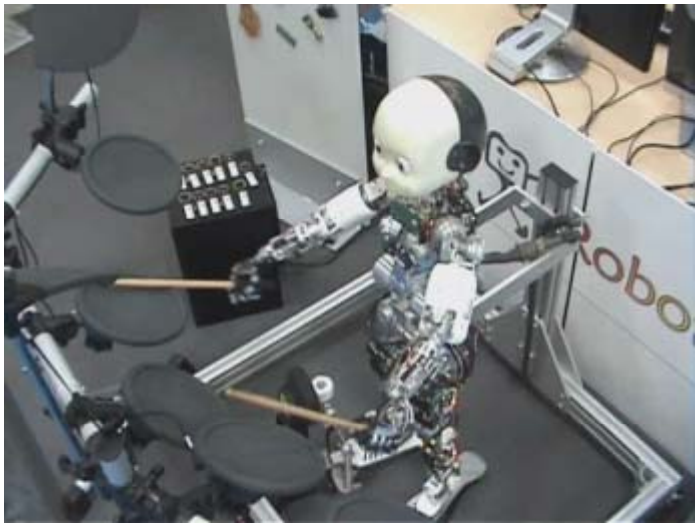






More examples…

With Peter Ford-Dominey (Inserm, Lyon)



With Auke Ijspeert, Ludovic Righetti, Sarah Degallier (EPFL)

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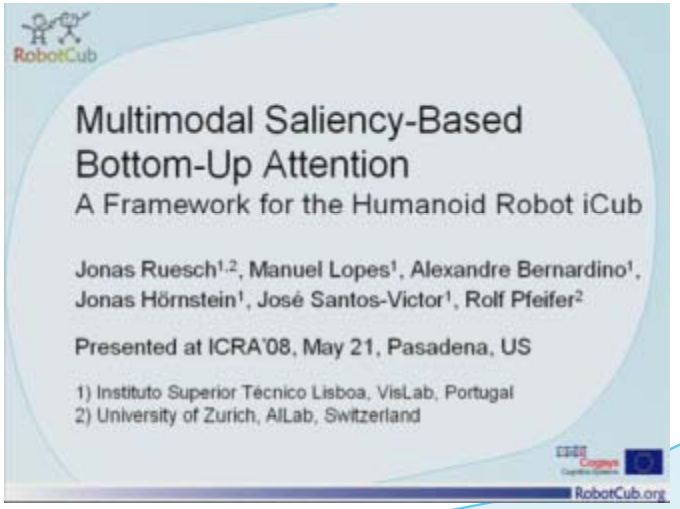

With VisLab (IST Lisbon)

Cogsys
Cognitive Systems

RobotCub

4 robots of the Open Call

People

- Giulio Sandini: Mentor & guidance
- Lorenzo Natale, Francesco Nori: Software, testing, calibration
- Marco Maggiali, Marco Randazzo: firmware, DSP libraries, tactile sensing
- Francesco Becchi, Paolo Pino, Giulio Maggiolo, Gabriele Careddu: design and integration
- Roberto Puddu, Gabriele Tabbita, Walter Fancellu: assembly
- Nikos Tsagarakis, William Hinojosa: legs and spine, force/torque sensors
- Bruno Bonino, Fabrizio Larosa, Claudio Lorini: electronics and wiring
- Luciano Pittera, Davide Dellepiane: wiring
- Mattia Salvi: CAD maintenance
- Alberto Zolezzi: managing quotes, orders and spare parts
- Giovanni Stellin: hand
- Ricardo Beira, Luis Vargas, Miguel Praca: design of the head and face
- Paul Fitzpatrick & Alessandro Scalzo: software middleware
- Alberto Parmiggiani: joint level sensing
- Alexander Schmitz: fingertips
- Nestor Nava: small Harmonic Drive integration
- Ravinder Dahiya: FET-PVDF tactile senors
- Lorenzo Jamone: fingertips
- Jean-Baptiste Keller, Daniel Roussy: construction
- Ludovic Righetti: simulation and initial torque specification